UV & Ozone for Secondary Disinfection

Treatment technologies for pathogens in pool & spa applications

By Ray Denkewicz

In the U.S., there are an estimated 10.4 million residential and 309,000 public swimming pools.[1] According to the U.S. Census Bureau, swimming is the fourth most popular sports activity in the country.[2] Unfortunately, a persistent problem exists: maintaining proper sanitization at each of the vast number of recreational water venues in the U.S.[3]

The Centers for Disease Control and Prevention (CDC) released a report citing 134 recreational water-associated outbreaks affecting almost 14,000 people in 2007 and 2008.[3] This was the largest number of reported outbreaks ever to occur during a two-year period recorded by CDC and is concurrent with the general rise in the reported number of recreational water illnesses (RWIs).

Astonishingly, 116 of the 134 outbreaks were associated with recreational water treated with at least one form of disinfection technology. Of these 116 outbreaks, 60.4% resulted in acute gastrointestinal illness (AGI), with the leading etiological agent being *Cryptosporidium*, which accounted for 83% of the AGI outbreaks. Other prominent pathogens associated with recreational water outbreaks noted in the CDC report include adenovirus, *Pseudomonas*, *Shigella*, *Legionella*, norovirus, *Giardia* and *E. coli*.[3]

The vast number of outbreaks and the large population affected are alarming considering that these data are only for a two-year period. Many other studies have confirmed that the CDC findings are not a few isolated incidences, but a persistent problem.[4,5,6,7] Such findings have not been lost on CDC. Through its efforts, the primary causal agent for these outbreaks has been identified, and a solution to the problem has been recommended in its recently issued Model Aquatic Health Code (MAHC).[8]

Recommended Solution

The MAHC is a voluntary guidance document designed to help educate, calibrate and align local and state authorities, facility operators, equipment manufacturers and regulatory agencies on the best available science and practices for public aquatic facility management. In a 600-plus-page document, the MAHC covers a broad range of topics associated with aquatic facility operation and management. On the issue of water sanitization, the MAHC is clear when it suggests that secondary disinfection technologies, such as ultraviolet (UV) or ozone, be recommended for all aquatic facilities but required for public aquatic venues designed for children under five years of age and for therapy pools. This is presumably because children and the elderly are at the highest risk for illness from *Cryptosporidium*.[9]

Table 1. Chlorine Effectiveness Against Common Swimming Pool Microorganisms

Microorganism	CT value (ppm-minutes)	% Inactivation	Temperature	pH	Reference
Cryptosporidium	5,300	99.9	25°C	7.0	11
Giardia	15	99.9	25°C	7.0	15
Adenovirus	0.75	99.99	5°C	7.0	13
E. coli	<0.25	99.99	23°C	7.0	12
Norovirus	0.07	99.99	5°C	7.0	13
Shigella dysenteriae	<0.05	99.9	25°C	7.0	14

Note: Chlorine is effective against most microorganisms, but not all. The CT value (or concentration times time value) to kill 99.9% of *Cryptosporidium* is reported to be 15,300 ppm-minutes. This means that you need 15,300 ppm of chlorine for one minute (or 7,650 for two minutes or 1 ppm for 15,300 minutes, etc.) to kill 99.9% of the *Cryptosporidium*. Practically speaking, commercial facilities can afford neither the downtime nor the high chlorine doses to achieve that goal.

Secondary Disinfectant Options

CDC's recommendation for the use of either UV or ozone as secondary disinfectants is logical and prudent given that the main causal agent in the majority of RWIs is *Cryptosporidium*, a pathogen that is resistant to the effects of chlorine (see Table 1). These types of microorganisms are known to have a tough shell-like exterior that is virtually impenetrable to the oxidative power of hypochlorite and other chlorine disinfectant derivatives.[10]

Cryptosporidium can survive in nominally chlorinated pool water for more than 10 days. Only at high levels coupled with long contact times can chlorine be made effective against these organisms. Such conditions are neither practical nor affordable for most commercial aquatic facilities.

Fortuitously, both UV and ozone are effective against *Cryptosporidium* and many other microorganisms found in water.[16] The efficacy of UV and ozone against these microorganisms is not new; it has been known for some time in both the drinking water and swimming pool industries. With UV, microorganisms are inactivated when the UV light breaks bonds within the DNA (or RNA, in the case of viruses). Ozone's oxidative power is sufficient to damage the cell membrane, causing the contents of the organism to spill out or simply to prevent it from carrying on life-sustaining functions.[17] It is logical, therefore, to consider combining the killing power of UV or ozone for *Cryptosporidium* with the potency of chlorine. The MAHC's direct treatment of secondary disinfection system options in aquatic facility management unambiguously places the subject of RWI mitigation front and center.

UV & Ozone

UV light has been utilized as a water disinfection method since the mid-20th century.[18] UV light, at a wavelength of 254 nm, inactivates bacteria, viruses and protozoa like *Cryptosporidium* by breaking the molecular bonds of RNA and DNA to produce dimers, which render waterborne pathogens harmless and incapable of reproduction and growth.[17] Moreover, UV has been shown to decompose monochloramine, dichloramine and trichloramine in aqueous solution by photolysis.[19]

The UV sensitivity of microorganisms is measured by the UV intensity times the exposure time (see Table 2). The intensity-time relationship is analogous to the concentration-time relationship for chlorine. Just like chlorine, UV sensitivity varies considerably from one microorganism to the next.[20] Bacteria such as *E. coli* and protozoa such as *Cryptosporidium* are highly sensitive, requiring UV doses of about 10 mJ per sq cm for a 99.99% inactivation. Most viruses (e.g., poliovirus), on the other hand, are less sensitive to UV, with doses on the order of 30 mJ per sq cm for a 99.99% inactivation. Adenovirus is one of the least sensitive microorganisms, requiring a UV dose of about 180 mJ per sq cm for a 99.99% inactivation. Hence, UV treatment alone cannot be expected to provide protection against all pathogens.

Table 2. UV Effectiveness Against Common Swimming Pool Microorganisms[20]

Microorganism	IT value (mJ/cm^2)	% Inactivation
Cryptosporidium	~10	99.99
Adenovirus	100-165	99.99
E. coli	4-11	99.99
Legionella pneumophila	6-9	99.99
Shigella dysenteriae	3	99.99

Note: UV light is effective against most microorganisms, but not all. The susceptibility of microorganisms is measured by the IT value (UV intensity times time). Intensity is commonly measured in mJ/sec*cm^2. The product of intensity times time is therefore in units of mJ/cm^2.

Table 3. Ozone Effectiveness Against Common Swimming Pool Microorganisms

Microorganism	CT value (ppm-minutes)	% Inactivation	Temperature	pH	Reference
Cryptosporidium	3-10	99	25°C	6-7	16
Giardia lamblia	0.5-0.6	99	5°C	6-7	16
Adenovirus	0.9	99	25°C	7	23
E. coli	0.02	99	5°C	6-7	6
Pseudomonas	0.01	99	25°C	7	23
Legionella pneumophila	0.5-1.5	99	25°C	7	2

Note: Ozone's effectiveness, like chlorine, is measured by its CT value (or concentration times time value). The CT value to kill 99% of *Cryptosporidium* is reported to be between 3 and 10 ppm-minutes. So using 6 ppm-minutes as a representative value, this means that you need 6 ppm of ozone for one minute (or 3 ppm for two minutes, or 1 ppm for six minutes, etc.) to kill 99% of the *Cryptosporidium*.

Ozone has been used as a disinfectant in water since the turn of the 20th century.[21] Ozone functions similar to chlorine derivatives in water, but is 2.2 times more powerful as an oxidizing agent than hypochlorite. Ozone spontaneously decomposes in water by means of a complex reaction pathway to generate hydroxyl radicals. It exists naturally as a gas and is typically dissolved in water through bubble diffusion. Because ozone gas is unstable and difficult to store, it is most efficient to produce it at the site of water treatment. The two most common methods of producing ozone are through dissociation of molecular oxygen by corona discharge and UV photolysis.

Most microorganisms are highly sensitive to ozone (see Table 3). For most bacteria and viruses, less than 1 mg/L of ozone is needed for a 99% inactivation.[13,24] Analogous to chlorine, the sensitivity of microorganisms to ozone is measured by the ozone concentration times the exposure time. Unlike chlorine, however, ozone does not provide a long-lasting residual, so it cannot be used as the primary sanitizer. Due to its disinfection and oxidation capabilities, ozone is a logical complement to chlorine.

Summary

CDC has made a clear case that sanitization for aquatic

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facilities needs to reach beyond chlorine if RWIs are to be mitigated. UV and ozone have been served up as two logical choices to act as a secondary disinfectant to chlorine. The efficacy of a combined chlorine/UV or chlorine/ozone system addresses the primary causal agent, *Cryptosporidium*, responsible for the majority of RWIs. Additionally, the multi-disinfectant approach provides a great one-two punch against a broad swath of microorganisms commonly found in pools and spas. As such, it can be anticipated that state and local health regulations will become embedded with the requirement for a dual disinfection strategy and the industry will see greater use of these disinfection technologies as part of the overall sanitization regimen within aquatic facilities.

This article is the first in a three-part series on UV and ozone. The next installment will appear in the June issue of *WQP*. **WQP**

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